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THESIS

TCP/IP IMPLEMENTATION CONSIDERATIONS FOR
ADMINISTRATIVE SCIENCES DEPARTMENT LOCAL AREA
NETWORKS

by

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The ability to rapidly access and exchange information by Department of Defense activities is critical to successfully accomplishing their mission. At the Naval Postgraduate School in Monterey, California, the need for connectivity with other organizations, such as research and other academic institutions is just as critical, with computer communications through the Internet providing this capability.
This thesis discusses the issues surrounding providing Internet connectivity through implementation of TCP/IP software in a LAN setting. Especially emphasized are the unique circumstances faced by the Administrative Sciences Department LAN managers in using TCP/IP in an academic LAN environment. Options for TCP/IP implementation are discussed, along with what would comprise the optimum LAN TCP/IP configuration, given various constraints.

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TCP/IP Implementation Considerations for
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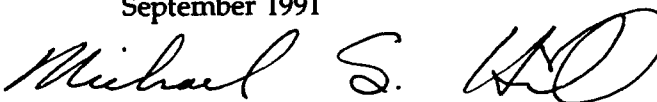B.S., Miami University

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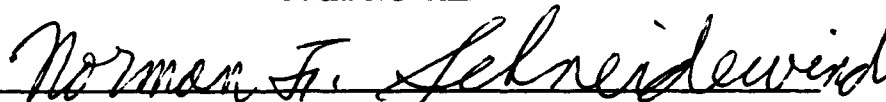
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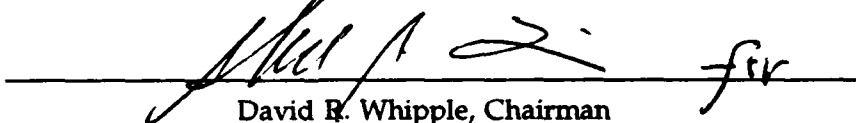September 1991

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ABSTRACT

The ability to rapidly access and exchange information by Department of Defense activities is critical to successfully accomplishing their mission. At the Naval Postgraduate School in Monterey, California, the need for connectivity with other organizations, such as research facilities and other academic institutions is just as critical, with computer communications through the Internet providing this capability.

This thesis discusses the issues surrounding providing Internet connectivity through the implementation of TCP/IP software in a LAN setting. Especially emphasized are the unique circumstances faced by the Administrative Sciences Department LAN managers in using TCP/IP in an academic LAN environment. Options for TCP/IP implementation are discussed, along with what would comprise the optimum LAN TCP/IP configuration given various constraints.

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I. INTRODUCTION

In many respects, the Department of Defense is an entity driven by the need for timely, accurate information. From battlefield to carrier battlegroup, office to organization, the ability to exchange information is vital to the accomplishment of any mission, as well as the effective and efficient administration of day to day operations. In a tactical environment, the term connectivity denotes a state of being able to conduct both voice and data exchange in a timely fashion, but in a broader sense this term can also imply the state of reliable communications between two geographically separated computers.

At the Naval Postgraduate School the need for the ability to exchange information with other organizations is just as important, with electronic communications between computer resources being a primary method of exchange. The principle method of achieving this connectivity is through the Internet, with a set of communication protocols derived from it known as Transmission Control Protocol/Internet Protocol (TCP/IP). There are a number of options for accessing remote computers using the Internet and these protocols, and after a brief overview of the major ingredients to achieving connectivity, a thorough discussion of alternatives for implementing them will be discussed.

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A. INTERNET BACKGROUND

The Internet as it is known today evolved from the ARPANET research that began in the 1960s. The Internet actually consists of the Defense Research Internet (DRI), National Science Foundation Network (NSFNET), and the Military Traffic Network (MILNET), which is part of the Data Defense Network (DDN) (Miller, 1991 p.223). These networks are connected to each other and users can send messages from any of them to any other, except where there are security or other policy restrictions on access. (Hedrick, 1988 p. 1)

1. What is Internetworking?

Internetworking, the ultimate goal of using networks such as the DDN, can be defined as: "communication between data processing devices on one network and other, possibly dissimilar devices on another network". (Miller, 1991, p.1)

> The internetwork, or internet concept is an extremely powerful one. It detaches the notions of communication from the details of network technologies and hides low-level details from the user. (Comer, 1990, p. 52)

With the ability to internetwork, the user now has the ability to conduct the exchange of information over very long distances in near real time. Information access and retrieval times decrease, along with an increase in the ability to share resources, a keystone of networking.

2. Internet Addressing

In order to get information from one computer to the other on a network (be it a local or a wide area network), each has to have an address, much like a mailing address for people.

a. Assigning Host Addresses

Each host on the Internet is assigned an integer address called its Internet address or IP address. IP addresses identify not only a unique host on the network but also the network itself. Addresses are actually comprised of a pair of addresses (netid which identifies the network connection and hostid which identifies the host) totaling 32 bits, which are allocated as follows:

> Class A addresses, which are used for the handful of networks that have more than 2^{16} hosts, devote 7 bits to netid and 24 bits to hostid. Class B addresses, which are used for intermediate sized networks that have between 2^8 and 2^{16} hosts, allocate 14 bits to the netid and 16 bits to the hostid. Finally, class C networks, which have less than 2^8 hosts, allocate 21 bits to the netid and only 8 bits to the hostid. (Comer, 1990, p. 63)

In order to simplify notation, this 32 bit number is broken up into 8 bit pieces known as octets, which are then written as four decimal numbers.

b. The Domain Name System Concept

When discussing the domain naming system, the term domain refers to an administrative entity that provides a decentralized management of host naming and addressing. (Stahl, 1987, p.1) While it is very efficient for computers

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to use bit patterns and even decimal numbers in addressing, these strings of numbers have little or no meaning to the average Internet user. By introducing the level of abstraction through the use of names, domain administrators are able to create names that have meaning, such as CC.NPS.NAVY.MIL which is the domain name for the NPS mainframe. Each part of the mnemonic name has meaning, for example, the MIL portion has been initiated by the NIC to act as a parent to subdomains that are developed by military organizations (Stahl, 1987, p.4). As the number of networks grow, so does the size of databases created to keep track of the mappings between decimal and mnemonic names. This concern led to the creation of a distributed, consistent system to keep track of this information which consists of the following parts:

- DOMAIN NAME SPACE, which is a specification for a tree structured name space.

- NAME SERVERS are server programs which hold information about the domain tree's structure and set information.

- RESOLVERS are programs that in response to user requests, extract information from name servers.

Conceptually, each part has its own unique view, including the user who only sees that to access information from any part of the domain name system (DNS) tree he initiates a call to a resolver. To the resolver, the DNS appears as an unknown number of name servers, each containing part of the tree. Finally, the name server sees the DNS of sets of separate

local information called zones. The name server has local copies of some of the zones, and periodically updates them from master files or other name servers. These name servers handle queries that arrive from resolvers using local zones. (Mockapetris, 1983, pp. 2-3)

A simplified way to view the process is as follows: a user wishes to find the address of machine Y @ UniversityZ. The query is generated by the resolver software in his machine to his local name server. The local name server does not have the address and therefore passes the query to the next name server in the tree. Potentially this process could traverse the entire tree looking for the address which it will eventually find or return an error message. If the address is found, the local name server will update a temporary database with this new information, and will store it for a specified period of time. After this, the information will have to be looked up again.

Network administrators wishing to establish and register a domain with the NIC will find Request For Comments (RFC) 1032: Domain Administrators Guide, very useful.

c. *The Distinction Between Names and Addresses*

While it may be intuitively appealing for the user to make the distinction between addresses and names, it is merely an artificial one. Names are merely a method of identification made up by characters in an alphabet. Names are

of use only when they can be effectively mapped to the object they denote. Therefore, IP addresses can be considered low level names and that Internet users prefer to use high level names for host computers. (Comer, 1990, p. 312)

d. *NPS Internet Address Structure*

Addresses are arranged in a hierarchical fashion with network given the first two octets and host given the last two octets. As an example, the address 131.120.254.1 is the address for the computer center, which also has the name server translation of CC.NPS.NAVY.MIL, which, unlike the four octet address, has the host on the left and the network on the right. Therefore, for NPS, the assigned network address is 131.120, with the computer center's address component being 254.1. Using this method of addressing, NPS will be able to provide addresses for up to 254 hosts, the numbers zero and 255 being reserved for specialized network addressing functions.

3. What is TCP/IP?

TCP/IP is actually a family of protocols that are 'sed for the transmittal of data packets (called datagrams) across the Internet. TCP (Transmission Control Protocol), MIL-STD-1778, is responsible for dividing messages into separate units of information or datagrams, reassembling them at the destination, re-sending anything that is not acknowledged as received, and reassembling them back into the correct order.

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IP (Internet Protocol), MIL-STD-1777, is responsible for the routing of the individual datagrams. (Hedrick, 1988 p. 3) IP is implemented on each Internet host and gateway between networks, and does not guarantee reliable delivery (Stallings, 1988, p.104).

4. Features of TCP/IP

In addition to the low level tasks, TCP/IP also has the following services available to the user:

a. Electronic Mail

Electronic mail allows the user to draft, send and receive messages to and from individuals or groups. The Simple Mail Transfer Protocol (SMTP), MIL-STD-1781, provides this service. (Comer, 1990, p. 4) SMTP makes use of TCP to establish a reliable connection for message transfer (Stallings, 1988, p. 104).

b. File Transfer

Using the File Transfer Protocol (FTP), MIL-STD-1780, users can copy and retrieve files from another computer to their own computer, or send files to another computer (Hedrick, 1988, p. 2). FTP supports ASCII, EBCDIC, and files, and makes use of TCP to establish reliable connection for file transfer (Stallings, 1988, p. 104).

c. Remote Login

The Network Terminal Protocol (TELNET), MIL-STD-1782, allows a user to log in to any other computer on the

network, and for remote terminal access to host applications. Under this protocol, the remote computer receives each character typed into the user's local terminal as if the user was using a terminal directly connected to it. (Hedrick, 1988, p. 4) TELNET makes use of TCP to establish a reliable connection for bi-directional terminal to host traffic (Stallings, 1988, p. 104).

d. Directory Services

TCP/IP provides facilities for the location of information and addresses of personnel who are registered users of the Internet through the use of naming services. For example, Internet supported functions such as WHOIS (name of person) will perform a search of a database, producing pertinent information on the person (such as associated institution and Internet address), if he is registered.

5. Why TCP/IP?

In addition to the services listed above, there are a number of features incorporated into TCP/IP that distinguish it from other network connection options:

- Network Technology Independence. TCP/IP is independent of any vendor's hardware.

- Universal Interconnection. A TCP/IP Internet allows any pair of computers to which has TCP/IP installed to communicate. Each computer is assigned an address that is universally recognized throughout the Internet. Each datagram carries the address of its source and destination.

- End to End Acknowledgements. The TCP/IP Internet protocols provide acknowledgements between the source and

ultimate destination instead of between successive machines along the same path, even when the two machines do not connect to a common physical network.

- Applications Protocol Standards. When designing applications programs that use TCP/IP, programmers often find that existing software provides the communication services that they need. (Comer, 1990, pp. 5-6)

These features provides the user with a standard, well-developed set of protocols which can be implemented on a variety of vendor hardware, fostering interoperability between systems. TCP/IP provides a bridge over dissimilar systems that can communicate and share resources.

While TCP/IP is referred to as one entity, one should always keep in mind that they are two separate entities, TCP providing for reliable stream transport service, and IP providing for the routing of datagrams between source and destination hosts. Additionally, one should also be aware of the dynamic functioning of IP, which unlike virtual circuit protocols (which provide for a static route of packet transmission), is constantly monitoring network traffic load conditions and at each node is looking for the best route for datagram delivery.

B. THE FUTURE OF TCP/IP

In August of 1990, the Government Open Systems Interconnection Profile (GOSIP) Federal Information Processing Standard (FIPS) v.1 went into effect. GOSIP will be comprised of the internationally accepted OSI protocols (i.e. X.25 for

public packet switched networks, X.400 for message delivery, etc.). This marks the beginning of formal attempts to bring the U.S. government, including the DOD, into the world of OSI which has been heralded as the universal architecture of the future. At face value, this would seem to dictate the end of TCP/IP and its plans for future implementations. But this is not the case:

> GOSIP 1 has not forced the spate of products necessary to build and operational internetworking environment with heterogeneous systems and networks. Full functioning internetworking will have to wait for GOSIP 2,3 and beyond. (Howard, 1990, p. 14)

TCP/IP is a mature product that has seen many improvements and enhancements since its inception. Given its relatively entrenched position in and outside of the DOD it figures to be an integral part of internetting in the coming decade. It is available now, therefore providing a proven, tested software package for internetworking.

C. ADMINISTRATIVE SCIENCES DEPARTMENT CONNECTIVITY GOALS

The ultimate goal of the Administrative Sciences (AS) Department is to achieve Internet connectivity through implementing a version of the TCP/IP software on a local area network (LAN), while at the same time, implementing an alternative that provides TCP/IP services in a form that is the most cost effective. Through TCP/IP, users will have direct access to the various networks and their host comput-

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ers, without the need for mainframe access. LAN implementation
of TCP/IP will make the Internet available to more users.

II. I – 224 LAN OVERVIEW

In order to understand the decisions facing the AS Department of how best to connect to the Internet, the implementation site equipment must first be described. The initial TCP/IP installation is I – 224. The following explanation will summarize the details of each LAN. Following these descriptions, an overview of present options for connecting to the Internet will also be discussed.

A. 3COM ETHERNET LOCAL AREA NETWORK

The 3COM LAN in I-224 is a small implementation of 3COM Corporation's network system based on the Institute of Electrical and Electronics Engineers (IEEE) Standard 802.3 Ethernet protocol. This network is also known as a thin Ethernet, referring to the thiness of the connective cabling which is smaller than the coaxial cabling used for the original Ethernet specification.

1. The IEEE 802.3 Ethernet Protocol

The heart of the IEEE 802.3 protocol is the approach of managing the communications channel by a method known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD). In this method of managing access to the transmission medium, a user computer listens to sense whether or not the network is busy (carrier sense); and if busy, it does

not transmit until the network is quiet. While transmitting, a computer listens for collisions with other computers trying to transmit, and if collision is detected, it immediately aborts transmission and issues a jam signal to let other computers know the failure and force them to reschedule their transmissions for a later time. To manage retransmission, user computers employ an exponential back off algorithm to avoid repeated collisions. Using an algorithm that increases transmission delay time in proportion to the number of sensed collisions makes retransmission time a function of network loading, thereby inducing transmission delay only as needed. (Schoch et al., 1982, p. 61)

2. 3COM LAN Construction

This thin Ethernet implementation is of both a physical and logical bus configuration. Each user computer has installed an ETHERLINK network interface board which provides the transmission and reception capabilities of Ethernet frames. To the end of each board is connected a three way connector which allows the coaxial cable to run between user computers. Cable ends that are not connected to another computer or the server are capped with terminating plugs that suppress cable end signal reflections. Figure 2.1 shows a physical diagram of the network.

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terminator   Coaxial Cable Ethernet Bus

Enet 1   Enet 2   Enet 3   Enet 4

Campus Backbone

802.3
Digital
Repeater

mrc-2000
cabletron systems
ethernet repeater

Special Purpose   IBM Proprinter   IBM Color   Enet 5
Server   Graphics Plotter
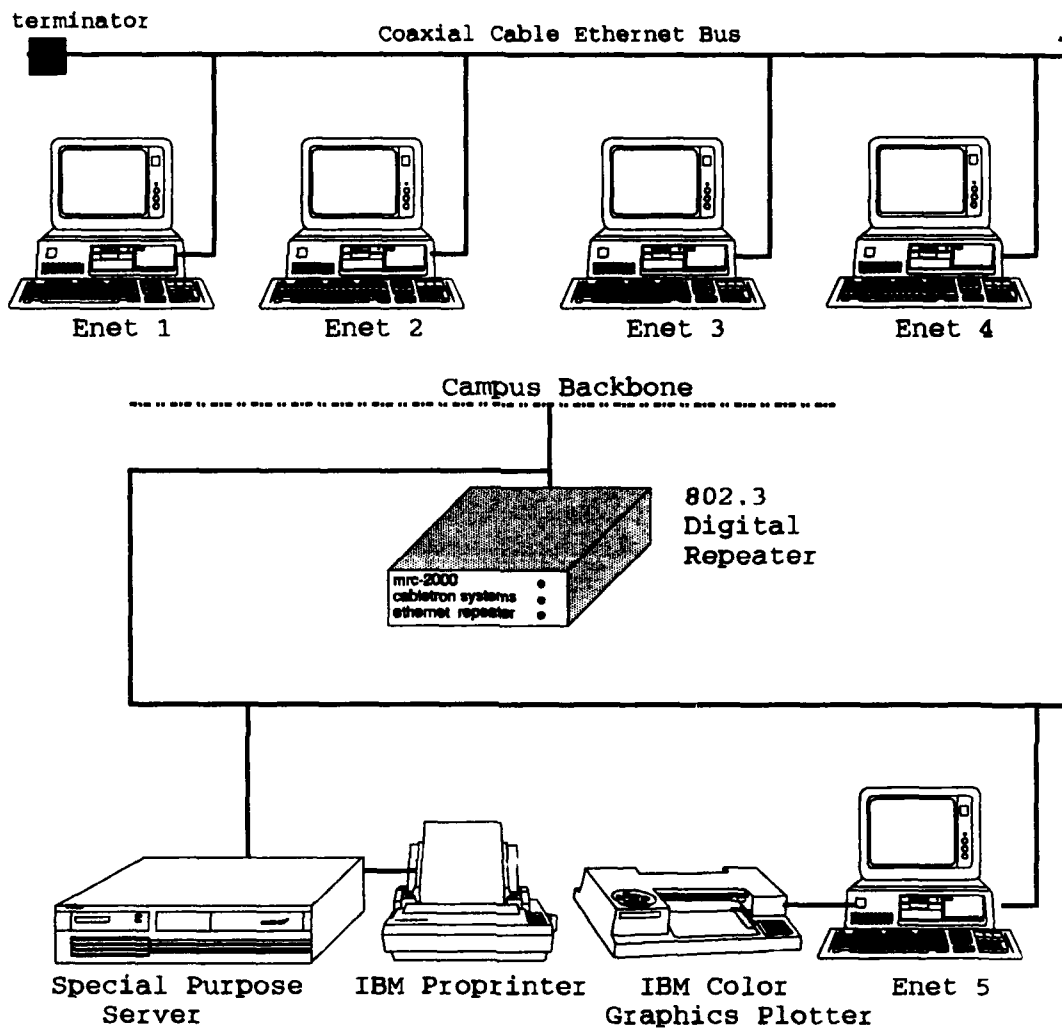
Figure 2.1 Administrative Sciences 3COM Ethernet Local Area Network

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3. Special Purpose Server

The term special purpose refers to the fact that the server for this network is not a regular computer (it is without keyboard and monitor), and cannot be used as such. Maintenance of the system is performed by placing the server in a maintenance mode and then accessing it through the use of one of the user computers.

a. Function

This computer makes available resources such as a printer, virtual disk drives and applications software for use by the computers on the LAN. The server also contains the network operating system and all the programs necessary to properly administer the network.

b. Server Hardware Characteristics

The Central Processing Unit (CPU) of the server is the Intel Corporation 80186, running at 8 Megahertz (MHZ). Server random access memory (RAM) is configured at 940 KB, and secondary storage for the network programs is provided by a 70 Megabyte (MB) hard disk drive. Additionally, the server has the following connection ports: AppleTalk, parallel port (connected to an IBM Proprinter), serial port (unused), and tape and disk SCSI ports.

c. Server Software Characteristics

In addition to DOS, the 3COM LAN currently uses ETHERSERIES 2.4 operating system software which provides the

following network services: electronic mail via the EMAIL command, network printing through use of the EPRINT command, the ability for users to create and share volumes of information on the server hard disk through the ETHERSHARE command, and general access of all ETHER functions through invoking the main menu via the EMENU command. Access to regular network application software is provided through the normal network 1DIR directory interface.

4. 3COM User Computers

The user computers provide the method for conducting information processing on the network. The 3COM network has five user computers, each an IBM PC XT with a Color Graphics Array (CGA) monitor. Originally running at a clock speed of 4.77 MHZ, they have all been outfitted with accelerator boards boosting speed to 7.2 MHZ. The computers also have 640 Kilobytes (KB) of RAM, two low density (360 KB) floppy diskette drives, and 20 MB hard disks which are used to hold the ETHERSERIES network operating system, DOS, and batch files. One computer, additionally controls an IBM color plotter.

5. Network Capabilities and Limitations

While 3COM corporation advertises that the maximum number of computers on a single network is 100 with a data transmission rate at 10 megabits per second (MBPS) for a thin Ethernet implementation, a practical maximum number of

computers on the network is ten. This is based on the relationship between network loading and actual system throughput. As network traffic increases, the likelihood of collisions increases, thereby decreasing throughput. In small applications CSMA/CD protocol networks offer relatively good performance, but in larger implementations experience reduced performance in the form of increased transmission delay times. (Stallings, 1984, p.37)

Another limitation of the network is its lack of redundancy in case of damage or failure. Since the server is unique to the network, its failure will cause network failure. Due to its bus design, any damage to the network cabling will also cause failure. Computers can be removed from the network but only by disconnecting them through unplugging the network board end of their T - connector.

B. IBM TOKEN RING NETWORK

The token ring network in I-224 is a relatively small implementation based on the IEEE Standard 802.5 Token Ring protocol. A larger LAN than the 3COM Ethernet, it consists of fifteen vice five user computers. The following is a discussion of network construction and characteristics.

1. IEEE 802.5 Token Ring Protocol

The main premise of the IEEE 802.5 protocol is that of managed access of the transmission media. Unlike CSMA/CD, which is a contention access protocol (each station competing

for the ability to transmit its particular data), users on the token ring must have permission in order to transmit their data. Managed access based on this protocol works in the following fashion: A high speed electronic signal (token) is continually circulated around the network. If a user wishes to transmit information, that computer captures the token, appends the data, and then sends it back out on the network. This token (now referred to as a busy token) circulates until it returns to the sender, at which time it is destroyed and then re-issued as a free token.

2. Token Ring LAN Construction

The token ring is logically constructed in a circular fashion but physically laid out in a star configuration. Transmission media consists of shielded twisted pair wire, also known as data grade cable. Special cabling connectors provide the ability to connect to a Multistation Access Unit (MAU) or to a cable extension. By use of MAUs, the network can be physically connected in a star, but still maintain the logical ring topology. This not only provides for easier maintenance and troubleshooting, but also takes advantage of the redundancy built into each MAU. Inside a MAU are two circuits. When there is a failure in one (a break in the ring), a set of normally energized relays fail to the secondary circuit maintaining network operations. User computers are connected to the network itself by installation of a token

ring adapter card (network interface board) which provides the hardware necessary for the transceiving of frames in the token ring protocol. Figure 2.2 provides a physical diagram of the network.

3. Server Characteristics

Unlike the 3COM Ethernet, the IBM Token Ring LAN has three server computers, each one a PC that has been selected to act as a server. To keep them from being used inadvertently by network users, all keyboards are kept locked by the Network Administrator.

a. *Server Hardware Characteristics*

Servers TN3 and TN6M are based on the Intel Corp. 80386 CPU running at a clock speed of 33 Mhz. Each has 4 MB of RAM (3 MB of which are set up as cache memory), a 212 MB hard disk drive, and both 5 1/4" and 3 1/2" floppy diskette drives. In addition to file servers, both TN3 and TN6M also function as print servers, each controlling an IBM Proprinter. TN0, the 3270 emulation gateway server also controls an IBM Color Jetprinter. TN3 additionally serves as controller for a Bernoulli Box 40 MB removable magnetic cartridge device. This unit provides increased program storage capability serving as logical drives I: and J: on the network, the unit having two removable 20 MB cartridges.

Server TN0, an IBM PC XT running at 7.2 Mhz,via an accelerator board, functions as a IBM 3270 terminal emulation
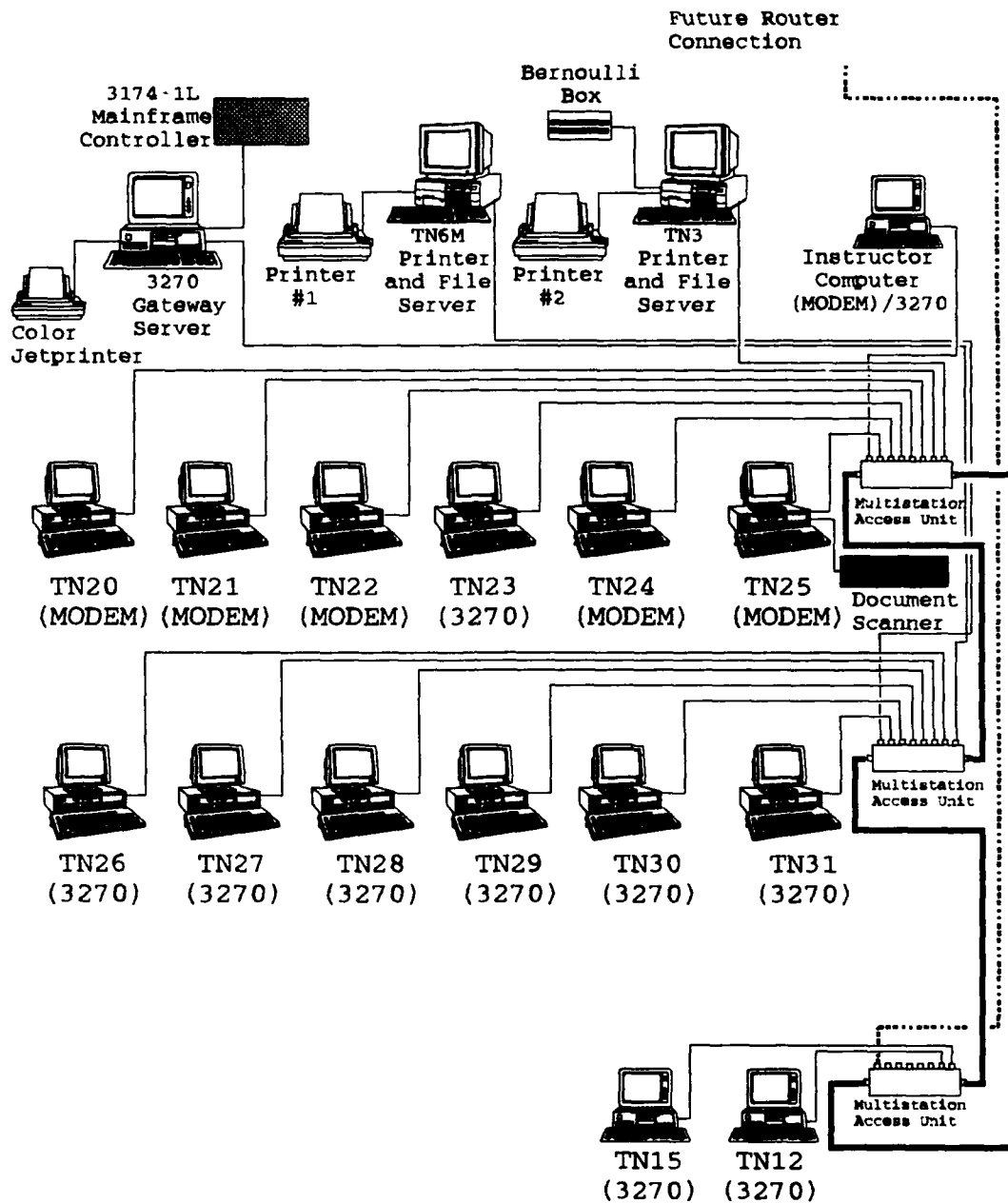
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Figure 2.2 IN 224 IBM Token Ring Network

gateway for connection to the Amdahl Mainframe located in the computer center. This computer also has a 10 MB hard disk for the storage of the 3270 gateway emulation software.

b. *Server Software Characteristics*

The token ring network uses IBM PC LAN version 1.2 as it network operating system in conjunction with DOS 3.21. Although this operating system does offer a PC to PC electronic mail functions this option has been disabled to increase available RAM.

4. Token Ring User Computers

The token ring has fourteen computers available for use with an additional one located in the front of the room for instructional use (output is connected to a three beam projector). Twelve of the user computers are Standard brand 80286 based computers running at 10 Mhz. These computers vary in their configuration in that TN20 through TN25 have math coprocessors and modems (except TN23 which has no modem but has 3270 emulation capability), while computers TN26 through TN31 all have 3270 emulation capability, but no coprocessor installed. In addition, user computer TN25 also controls an AST TurboScan graphical image scanner. These computers also have EGA monitors (except TN23 which has a CGA monitor), 640 KB of conventional RAM plus an additional 512 KB of extended memory which has been configured as a VDISK for network

programs. All user computers additionally have 5 1/4" floppy diskette drives (both high and low density), and 20 MB hard disk drives.

The remaining three computers, TN18, TN12, and TN15 are all IBM XT model computers with accelerator boards boosting their clock speed to 7.2 MHZ, 640 KB of RAM, 20 MB hard disk drives and CGA monitors. These computers also have two low density diskette drives and 3270 mainframe emulation.

5. Network Capabilities and Limitations

From a maintenance standpoint, the token ring is far superior to the 3COM in a number of ways:

- MAU redundancy provides improved network reliability.

- Failure of a server, while degrading the network, can be remedied by replacing it with a reconfigured user computer.

- User computers can be added or removed without degrading network performance.

In addition, the token ring protocol, while incurring token passing delay, guarantees access to the media, and is therefore more suitable for higher traffic loads. Physically, the network simply offers more of everything: computing power, printing services, and secondary storage.

C. INTERNET CONNECTIVITY

This section will discuss the methods presently available for accessing the Internet as well as the existing and

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proposed physical connections involved in establishing direct connectivity between the Internet, 3COM, and token ring networks.

1. Mainframe TCP/IP Access using 3270 Emulation

In order to connect to the mainframe and access TCP/IP, one could use 3270 emulation with a coaxial cable connection to the mainframe. IBM's 3270 Terminal Emulation Software is designed to be used in conjunction with a 3270 emulator board to create a "virtual" 3270 terminal that can directly access the mainframe.

a. *Physical Connection*

In order to provide the most efficient means for achieving 3270 emulation capability for the network, a gateway installation option was chosen. With this option, the 3270 gateway has the 3270 emulation adapter and the gateway software installed, which is in turn connected by coaxial cable to an IBM 3174 Mainframe Controller, located in the computer center.

b. *Software Installation*

Although none of the user computers on the 3COM network are configured for 3270 emulation, ten computers on the token ring have been given this capability, although only five can concurrently access the mainframe at a time. The gateway server, upon boot up, is put in the 3270 mode and establishes an on line connection to the mainframe. The user

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computers which have the 3270 emulation software installed on their C drives, which is invoked via a batch file from the L: drive (batch file directory), will map the keyboard for 3270 terminal operations and establish connectivity through the gateway with the mainframe. Once logged on, then the user simply uses the mainframe's TCP/IP to conduct a TELNET or FTP operation. While this does provide connectivity, this method of interconnection is much less elegant than using the mainframe directly.

2. Connecting to the Internet Using the TAC

The TAC or terminal access controller is a specialized computer that can connect directly to the packet switching node located in the computer center at NPS, and provides terminal logic for controlling a terminal and communications logic for establishing connections across the Internet to host systems (Stallings, 1988, p. 103). To access the TAC from the token ring network, the user would use a resident modem communications software package such as SMARTCOM, to connect to the TAC.

While this connection bypasses the mainframe entirely, it does not provide full TCP/IP capability. Full use of the Internet requires host access, which allows information transfer between hosts connected to the Internet (Stallings, 1988, p. 103). Functions such as FTP, TELNET and SMTP are not directly available.

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3. Gateway To The Internet

In order to implement TCP/IP on the two local area networks, it will first be necessary to physically connect them to the campus backbone. Connection via a gateway to the backbone will enable the TCP/IP software to address the correct router which will in turn route packets out on to the Internet. The following discusses each connection.

a. *3COM Ethernet Connection*

The 3COM network has already achieved Internet connectivity in the following manner: a cable has been run from the 3COM server to a Cabletron Systems MRC-2000 ethernet digital signal repeater. The repeater reshapes and retimes digital pulses to ensure that ethernet frames maintain their integrity. From the repeater, a cable has been connected to an ethernet transceiver, which taps the Ingersoll branch of the campus backbone.

b. *Token Ring Connection*

Recent improvements to the NPS Internet architecture have seen the addition of a Cisco Router to the campus backbone. The router which is capable of simultaneously supporting a number of different communication protocols, is the device through which the token ring LAN will achieve Internet connectivity. When the connection is implemented, it will be constructed in the following manner: a cable (already run between I-224 and the Computer Center) will be connected

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to a token ring interface board installed in the router; the router will then retrieve the IP datagrams from the token ring frames and then route them directly to the Internet via a high speed data communications line. These connections will provide the ability for direct access to the Internet, and thus pave the way for network TCP/IP implementation.

While LAN users presently have the ability to use Internet resources, they are limited in scope. Certain functions such as mail and file transfer can only be accomplished at the mainframe level of access. The following chapter will discuss these issues in addition to how best implement TCP/IP.

D. CHAPTER SUMMARY

This chapter began with a discussion of the 3COM Ethernet LAN and the IBM Token Ring network. Hardware and software features were discussed, along with the protocols employed by each network. Currently available methods for connecting to the Internet were discussed, including using SIMPC and the TAC, and the chapter concluded with a discussion of the physical connections necessary to achieve connectivity from either LAN to the Internet.

III. TCP/IP INSTALLATION OPTIONS

This chapter will focus on both the currently available and not yet available "ideal" alternatives for installing TCP/IP protocol software on the networks reviewed in Chapter Two. First, however, is a discussion of a factor that greatly influences the selection of a specific alternative – Internet addressing.

A. INTERNET ADDRESSING METHODS

The host addressing method is shown in Figure 3.1. From the diagram it can be seen that when this method of Internet connectivity is chosen, given a class B address with 254 possible hosts, the network could soon run out of addresses, eventually requiring address restructuring. However with the use of subnetting for Internet connectivity, this can be kept to a minimum. Figure 3.2 illustrates.

As previously discussed, the first two octets of the NPS Internet address comprises the network number (131.120). What is done with next two octets is the decision of the campus network administrator and the LAN administrators.

Again, while this may not seem important in the context of the AS Department, when applied to larger installations, the

Flat network Architecture consumes a lot of address space.

Campus Internet Backbone

Host	Host	Host	Host	Host	Host

131.120.254.30 131.120.254.31   131.120.254.32 131.120.254.33 131.120.254.34   131.120.254.35
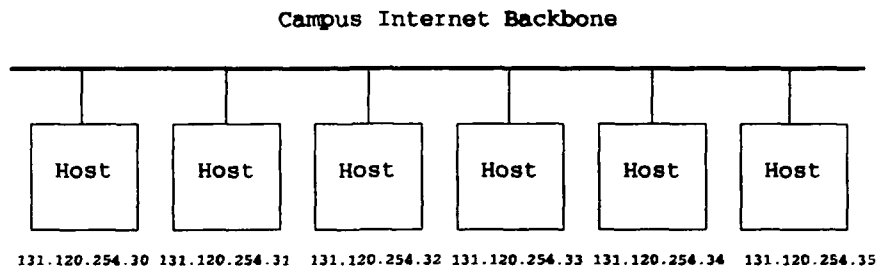
(PC hosts on the same Local Area Network)

Multiple connections on the campus backbone.

Figure 3.1 Local Internet Architecture without Subnetting

Subnetting promotes logical understanding of Internet structure.

Campus Internet Backbone 131.120.254.X

Subnet Gateway
131.120.30.1

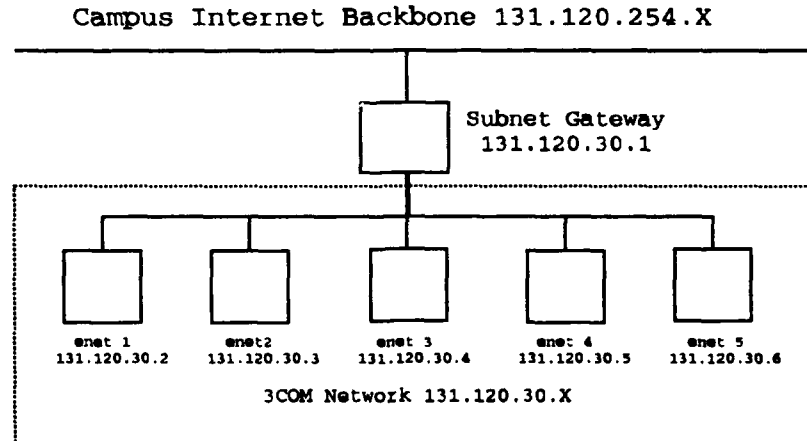| enet 1	enet2	enet 3	enet 4	enet 5
131.120.30.2	131.120.30.3	131.120.30.4	131.120.30.5	131.120.30.6

3COM Network 131.120.30.X

Figure 3.2 Subnetting

implications of this become apparent: As the number of local area networks grow, the more subnetting makes sense.

B. PC HOST OPTION

This section covers the first option currently available, that of installing TCP/IP on each user computer, essentially making it into a network host. Figure 3.3 illustrates the host implementation for the IBM token ring.

1. What Is A Network Host?

Generally speaking, a host on a network is an applications computer that may also have communications protocols necessary to operate on that network. In the context of the Internet, hosts are registered at the Network Information Center (NIC), which assigns them specific IP addresses. In the case of NPS, which has been assigned the class B address 131.120.X.X, NPS locally administers address numbers created below the 131.120 level.

The domain name NPS.NAVY.MIL has been registered with the Internet authority (NIC). Further subdomains, which are comprised of the names for machines connected to the backbone, are controlled by the local NPS network authority. It is the responsibility of the organizations wishing to connect to the backbone to first request connection to the backbone and obtain a group of Internet addresses in order to maintain local Internet integrity.

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INTERNET

Cisco Router
131.120.31.1

Note: Token Ring
connects directly to
router via cable run
from MAU, bypassing
backbone.

IBM TOKEN RING   **131.120.31.X**
(logical view)

PC Host
131.120.31.2

TCP/IP resident on
each PC.

PC Host
131.120.31.5
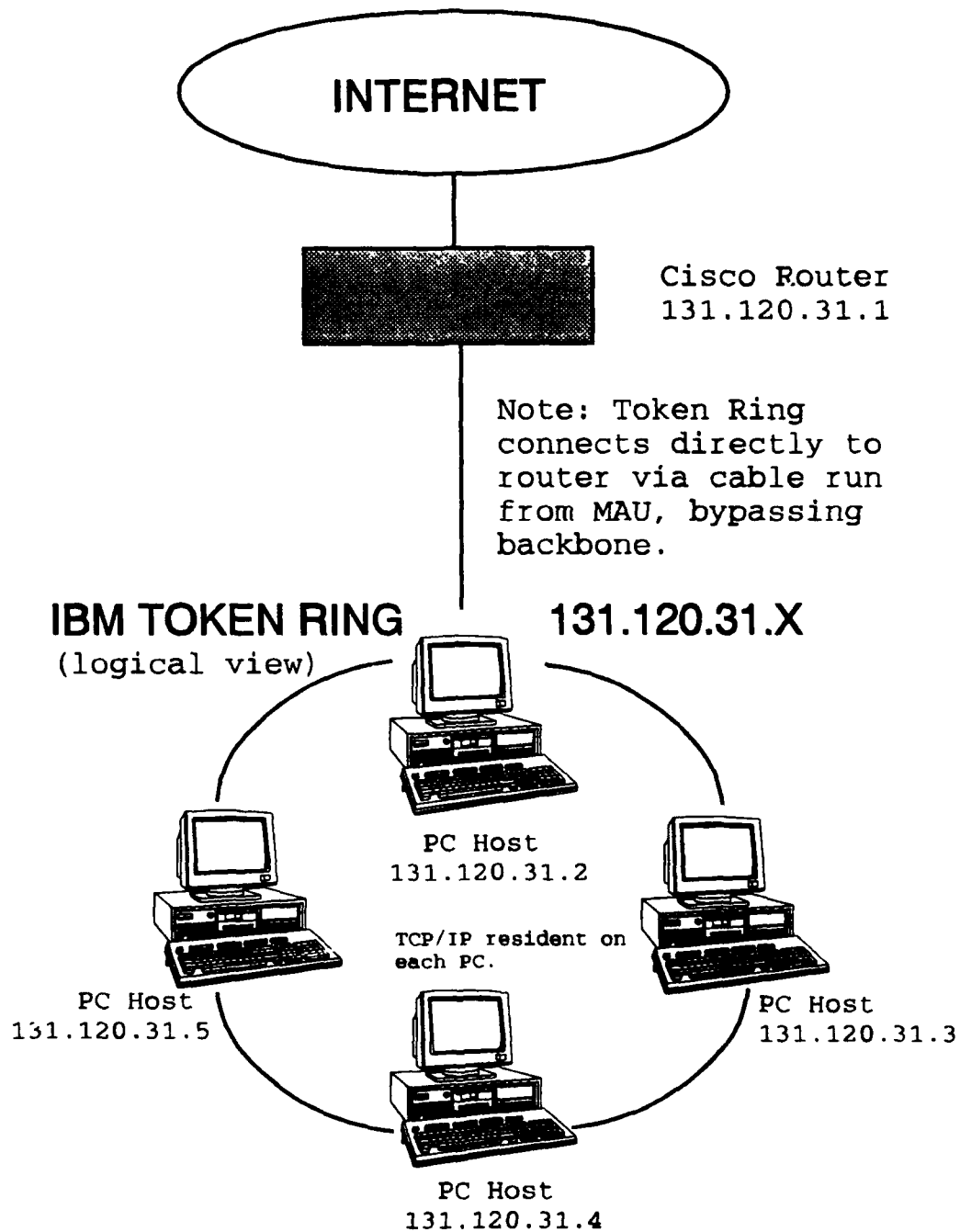
PC Host
131.120.31.3

PC Host
131.120.31.4

Figure 3.3 PC Host Option on the IBM Token Ring

2. Implementing the PC Host Option

The following is a discussion of points that should be considered by a network administrator when evaluating the possibility of assigning each LAN PC as a host on the Internet.

a. Benefits of Creating Individual Hosts

Installing TCP/IP on each user computer will enable it to enjoy all the services inherent in the software. When each computer has its own address, functions such as FTP, TELNET and E-Mail can be conducted between PCs. To see why this is important, understand that in order to conduct these operations, users must have an address in order to transfer files, log on to another PC, and receive mail.

b. Requirements

The first requirement in creating individual LAN hosts would be the availability of sufficient hard disk drive space for permanent software installation. In the case of the AS Department LANs this is presently not a concern as the user PCs have an average of 10 MB of free disk space, while the PC TCP/IP software only requires about 3 MB.

The second requirement would be to obtain a block of addresses from the local Internet administrator. These must be obtained for software installation, since these will be used to set the pathway for the routing of datagrams, and also

to enable him/her to maintain control over the campus network structure.

Finally, the LAN must be physically connected to a router that has access to the Internet. For the AS Department LANs this has been partially accomplished by connecting the 3COM Ethernet to the campus backbone. While a cable has been run to connect the token ring, this has not yet been accomplished.

3. E-Mail Considerations Under the Host Option

Individually addressed PCs enable the user to either send or receive mail over the Internet. However, in the case of the AS Department, a number of questions arise concerning the viability of this option. The following are points for consideration:

- User PCs in I-224 are powered down when not in use. Any attempt to send mail to these computers would result in a host unreachable condition.

- LAN labs are public domain in the sense that any student can use them. However, many students will probably wish to have their own Internet Identifier and E-Mail address, entailing significant administrative overhead.

- An alternative to individual addresses would be the use of generic addressing. Users, however would have to remember to identify themselves when sending messages.

- If generic addresses are selected, E-Mail privacy will be nearly impossible to maintain with a large number of users.

- Large amounts of E-Mail will probably not be discarded by users and will accumulate on the network, creating an administrative burden on the LAN administrator, who will eventually have to purge it. (Schneidewind, 1991, p. 2)

Although some of these considerations are peculiar to the AS Department and similar environment LANs, they can easily be fit into the context of larger organizations, where these issues take on much greater significance.

4. Problems With The Host Option

While most TCP/IP services are currently available with this option, there are also a number of problems:

- Complicated installation and set up procedures in addition to software maintenance on each machine will significantly increase network administrative overhead. Effort required is multiplied by each TCP/IP machine on the network and could prove to be prohibitively expensive over time.

- Each separate TCP/IP installation will require approximately 3 MB of hard disk space cumulatively consuming significant amounts of storage space for the network.

- Naming and addressing issues, depending on the method chosen, could involve extensive coordination between the campus Internet authority and the LAN administrator.

Another consideration which should not be overlooked is the expense involved in setting up multiple TCP/IP installations. While in the case of I-224, this may seem a trivial, it has broader implications when considering implementation on larger LANs.

Finally, the point should be made that at present there is not a product available that addresses the above concerns. While there are a number of PC TCP/IP products available, each has its own peculiarities, especially with regard to user services. Network administrators will have to

carefully evaluate each product to see not only if it will function on a particular network, but also if it provides the desired functionality.

Part of the problems associated with the host option is that the predecessor protocols of TCP/IP were originally designed to be run on large mainframe computers that were designated as hosts on a wide area network. As technology has improved, and with the advent of distributed systems, problems such as the ones noted above are more frequently encountered. This is due to the fact that users are looking to use TCP/IP in ways other than originally intended; that is for implementation on those distributed systems in ways that provide all of the functionality, but do not require all the costs involved in a PC host set-up. This is proving difficult at present, since this would require significant re-engineering of software that was previously designed for minicomputers and mainframes.

The following section will address an alternative to individual PC hosts: the gateway server option.

C. TCP/IP LAN GATEWAY OPTION

While creating a TCP/IP gateway will eliminate a number of the concerns outlined in the previous discussion, it will also generate others. First, however, is a discussion of some fundamental points necessary to understand how this option could be implemented.

1. What Is A Gateway?

In simplest terms, a gateway is a computer that interconnects two separate networks and passes packets between them. Terms also used to describe them are internet gateway and IP router. (Comer, 1990, p.55) When looking at implementing TCP/IP on a gateway server for either of the LANs in I-224, the requirements are basically the same: the server computer has a physical connection to another network (i.e. the 3COM Ethernet has a connection to the campus backbone), and this gateway server must format data in accordance with network protocols (i.e. ethernet packets would be converted to IP datagrams before transmission on to the backbone).

Internet gateways employ a number of gateway specific protocols in order to determine the best route for routing datagrams across the Internet. These protocols deal specifically with actions such as updating internal dynamic routing tables, these tables contain an entry for each reachable network, and information about which of its neighbor gateways (a neighbor gateway shares a common network), and are currently operational.

2. Implementing A Gateway

In order to implement this option either an existing server will have to be configured with the TCP/IP software, or possibly another computer would be dedicated as a TCP/IP server.

a. *Gateway Set-Up*

In setting up a gateway server there are a number of requirements that will have to be fulfilled. First, the computer, as noted in Chapter I, must have physical connectivity with the campus backbone in order to communicate on the Internet. Second, it must be configured with the TCP/IP software, and also set up to function as a gateway, including giving it an address.

b. *Gateway Operation*

The gateway server will function the same as any other file server on the network. That is a user computer will initiate access to the server to load the TCP/IP program. The applicable software will be copied into the user computer RAM and executed.

c. *Advantages and Disadvantages of a Gateway*

The following are the main advantage and disadvantage of the gateway option:

- Centralized Maintenance. TCP/IP software is limited to one installation per network, meaning less man-hours necessary for maintenance such as software updates.

- Under current implementations user computers will still need individual Internet addresses in order to operate in the TCP/IP environment. User PCs are designated to the system during software set-up.

The disadvantage listed above is common to a number of vendor PC TCP/IP products when installed under a gateway configuration.

3. Limitations of Current Host and Gateway TCP/IP Options

In addition to the above limitation, certain current TCP/IP products have the following limitations that are common to both options:

- Certain vendor TCP/IP products require set-up of a separate FTP server in order to provide this service. While it is possible to make this resident in the gateway server, it is undesirable from a performance standpoint unless the server is of a robust design (i.e. 486, very large hard disk). For networks such as the 3COM Ethernet, this would entail a separate computer due to the limited capability of the special purpose server.

- Certain vendor TCP/IP products require set-up of a separate E-mail server in order to provide SMTP. Some of these implementations only run under the UNIX operating system.

The above limitations result in the loss of a lot of potential TCP/IP functionality. (Schneidewind, 1991, p. 8)

This concludes the discussion of currently available alternatives. The following section proposes a system design that provides both the LAN administrator and LAN user with the best features of both alternatives.

D. MODIFIED GATEWAY OPTION

This section is proposed as an "ideal" system which will combine the best features of systems previously discussed, while proposing a more conservative use of resources.

1. Components of the System

The following subsections discuss the components of the modified gateway server option. All components could either be logically implemented (configuring the appropriate

software to achieve the desired functionality), or physically implemented by designating that specific function to a separate computer. Figure 3.4 depicts the total system.

a. Gateway Server

Like the gateway server option previously discussed, this system will have a server computer with TCP/IP resident on its hard drive, just like any other application program. The TCP/IP server will be accessed via a batch file located on each user PC, and will serve as the central point of entry to the Internet from a specific LAN, and will physically connect to the campus backbone.

b. Name Server

This configuration will employ a name server for the network. While this will only be a software configuration for small LAN implementations, larger size LANs or LANs that have other LANs using the same gateway server will benefit from a specific computer designated as a name server for both performance and administrative reasons. A name server will provide the ability for translation of mnemonic names (e.g. MichaelH @ 3COM.AS.NPS.NAVY.MIL) to a E-Mailbox address such as 131.120.30.7, while freeing the gateway itself from having to conduct potentially long database searches. Requests for names translation will be shunted to the LAN name server.

Campus Backbone

TCP/IP Gateway Server
Note: This server
conatins TCP/IP
software and has
physical connectivity

FTP/E-Mail/LAN Name Server

Note: This server contains
mailboxes for all registered
LAN TCP/IP users.

TCP/IP Users. TCP/IP transient in user computers.
Files and E-Mail available at the user computer only
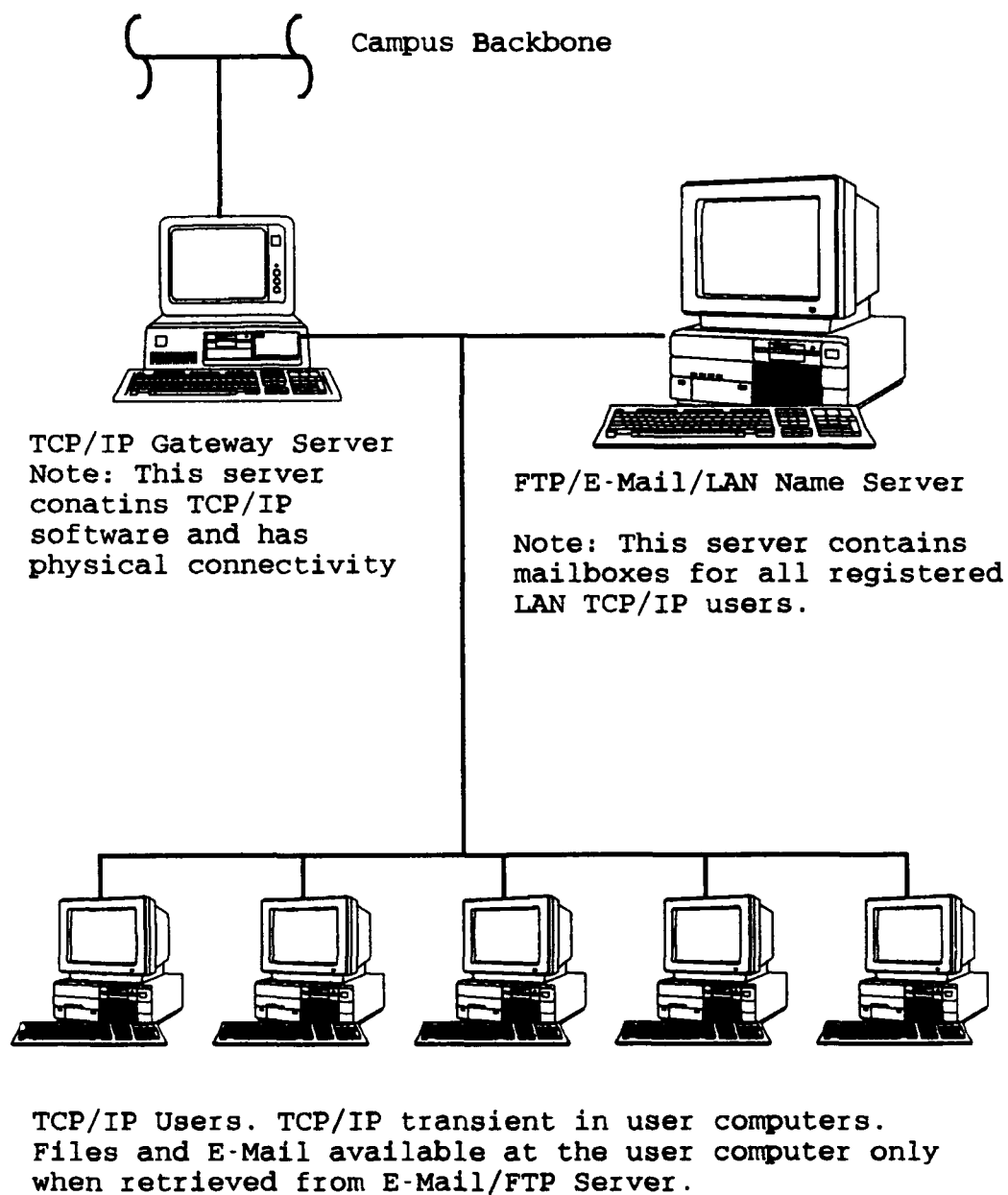when retrieved from E-Mail/FTP Server.

Figure 3.4 Conceptual Diagram of Modified Gateway Option

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c. *E-Mail/FTP Server*

The third component of this configuration will be an E-Mail/FTP server. This component, either logically or physically configured, depending on network size, will serve as the repository for all incoming electronic mail and files. Instead of having mail and files going directly to each user PC on the LAN, they will remain at the mail server, until retrieved by the user.

This approach provides E-Mail, FTP, and TELNET services, while unburdening the server to provide the essential portions of TCP/IP functions such as routing and error checking. The following subsection deals specifically with the method of operation.

2. Method of Operation

The system will operate in the following manner: a user desiring to use TCP/IP will select it from the menu on the network by invoking a batch file. This batch file will require that the user enter a name and a password. Upon confirmation, TCP/IP will be accessed on the gateway/server and the name server will be accessed. This call will retrieve the mailbox address that corresponds to the user and all subsequent E-Mail/file traffic for the user will be routed there. In actuality, all addressing will originate at the servers, with all FTP, TELNET and E-Mail functions handled for the user by servers. Users will be able to command these

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functions without requiring user PCs to carry out these functions directly. User PCs will not require Internet addresses. A separate, non-Internet address method will allow user PCs to communicate with servers (i.e. FTP, E-Mail). The user will send his traffic as he would in any other TCP/IP installation. For receiving it, however, it will go to his mail box on the mail server, where he will have to retrieve it locally via a separate program much like using TCP/IP on the mainframe. When users log in to the TCP/IP network, they will be notified if they have any mail or files in their mailbox. They then have the option to browse, copy to a local disk drive, or discard.

a. *Advantages of the Modified Gateway*

By using a modified gateway approach to TCP/IP implementation on a LAN, The following benefits will be realized:

- PC to PC file transfer ability. Using a modified gateway will provide PC to PC file transfer ability without implementing individual hosts.

- Centralized maintenance. Software, aside from invocation batch files, will only be resident on the server(s), greatly reducing LAN maintenance.

- Centralized E-Mail. E-mail, which under the host option would accumulate in each user computer requiring periodic purging, now resides centrally on the server where it can be more easily managed by the LAN administrator.

- User name service. By implementing a name server which will be used to link names with electronic mail boxes, users will be able to have their own virtual address from which other Internet users can reach them.

- TELNET availability. Provides for TELNET operations between computers external to the LAN and the LAN servers.

- Conservation of resources. By setting up a gateway, individual TCP/IP installations are no longer necessary, saving user hard disk space. The software is executed much like any other application program stored on the server.

- Economy of addressing. Large numbers of PC hosts make for large Internet routing tables. Gateways will serve as the IP address point as opposed to individual installations which will need as many addresses as there are TCP/IP user PCs.

- Simplified network structure. Gateways complement subnetting which will in turn present to outsiders a simpler view of the campus network structure.

- Lower campus network overhead. The campus Internet administrator will have less maintenance in the areas of name server and routing table maintenance.

This approach to providing TCP/IP service yields the most functionality and also the most benefits to both LAN user and LAN administrator.

b. *Modified Gateway Disadvantages*

This option, while providing all services necessary to the Internet user is not without its disadvantages, these being the following:

- Option is currently unavailable. To the author's knowledge, this option is only conceptual and is not currently offered by TCP/IP software vendors. For this capability to be offered, vendors must be made aware of the need by users.

- Power failures/glitches will cause losses of E-mail/files. Given the centralized implementation of this option, which, unlike an implementation of individual hosts, a power loss or severe fluctuation could cause the server to become inoperative, resulting in host unreachable conditions, or even worse, loss of a disk drive resulting in loss of all accumulated traffic. (Schneidewind, 1991, p. 7)

- Academic setting may preclude prompt network recovery. The LAN labs are designed mostly to run unattended. A loss of power or a glitch that requires a server reboot may go unnoticed for hours or even days, causing a severe disruption of service.

- Name server maintenance overhead. Given a large number of students who may desire their own personal Internet address and who are transient, will require frequent additions/subtractions from the name server database by the LAN manager.

- Name Server operation. A decision that will have to be made is if it is decided to operate a local name server, will it be designed to Internet standards? Specifically, will it replicate its information at another location on another name server to preclude service interruption in event of primary name server failure?

With this alternative, LAN users will have the same services available to them as mainframe TCP/IP users, but without having to use software packages such as SIMPC to communicate from LAN PCs to the mainframe simply gain access to TCP/IP.

E. CHAPTER SUMMARY

This chapter first discussed basic concepts such as gateways and subnetting before examining the currently available TCP/IP host option, an implementable gateway option, and the conceptual modified gateway option. It was first determined that a PC host gives all the functionality desired in a TCP/IP application, while being human and hardware resource intensive. The gateway option, while eliminating the problem of individual TCP/IP installations, does not eliminate the problems of assigning Internet addresses to individual ma-

chines, nor the lack of privacy and data integrity. Finally, the modified gateway option was discussed as an ideal alternative for providing TCP/IP services, while minimizing LAN manager labor.

IV. RECOMMENDATIONS AND CONCLUSIONS

This paper began with a general discussion of the Internet, its importance, and why the Administrative Sciences Department is currently implementing TCP/IP on both networks in IN-224. The body of this paper dealt with the various options to consider for implementation on either network, with an emphasis on factors such as maintenance and functionality. Final recommendations will summarize this thesis.

A. TCP/IP IMPLEMENTATION OPTIONS FOR IN-224 LANS

Three options for implementation of TCP/IP on the local area networks in Ingersoll 224 were discussed at length in the body of this thesis. One of the main concerns that surfaced in all of the options is that of electronic mail service provided by SMTP. Concerns were expressed about maintaining E-Mail privacy and file integrity, and on limiting the amount of LAN manager labor that would be required to achieve privacy and integrity.

Architectural considerations were also discussed when examining the campus Internet. Based on those considerations, the following policies should be adopted: use subnetting combined with either the gateway or modified gateway option for LAN implementation. It should be noted that subnetting is

being used in I-224 combined with a limited form of the gateway option. The preferred option – the modified gateway option, should be implemented whenever it is available from vendors. Refer to Figure 3.4 for an illustration of this option.

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